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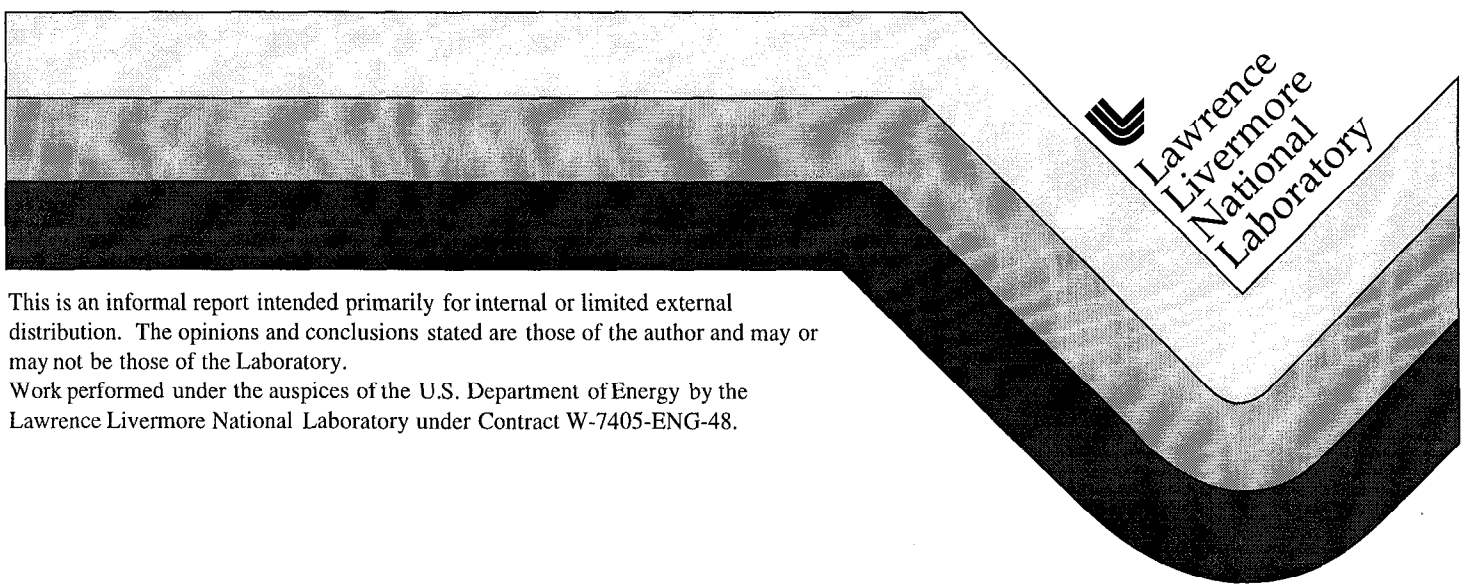
Characterization of Russian ballistic furnace shells

Evelyn Fearon

February 18, 1999



Target Area Technologies

Mail Station L-474

Ext: 31817

February 18, 1999
TAT 99-003.2M

To: Bob Cook

From: Evelyn Fearon

Subject: Characterization of Russian ballistic furnace shells

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We received another batch of polystyrene ballistic furnace shells on December 4, 1998. Assigned the batch number of LSC012, it consisted of three cassettes containing 36 shells in each cassette. A group of 27 of the shells were selected for characterization that ranged in diameter from 1880 to 1780 μm. There were two shells with a diameter above 1900 μm, but they were too fragile and did not survive initial handling.

For characterization, we examined the shells through a stereo microscope, measured diameter and sphericity on RACI, and weighed a subset of the 27 shells that did not have large particles or polymer shards adhered to the outside in order to calculate wall thickness. We then selected the cleanest and most spherical shells for Sphere Mapping.

This batch of shells has about the same physical appearance as the one we documented August 26, 1998 (memo TAT 98-047.2M). There were some shells with polymer shards adhered to the outside, a few large vacuoles or large particle embedded in the polymer wall, and some with a scattering of small black particles on the outside. There were no swirls in the shell walls.

As mentioned in the previous report, each shell is measured with the RACI system in three orthogonal views. We now have new analysis software on RACI that returns the mode two amplitude of the sphere *radius* vs. angle of rotation around the edge of the shadowgram of the shell. From this we report the maximum radius out-of-round, the largest of the three different orientations. Figure 1 is an example of one such trace and the data annotated on it.

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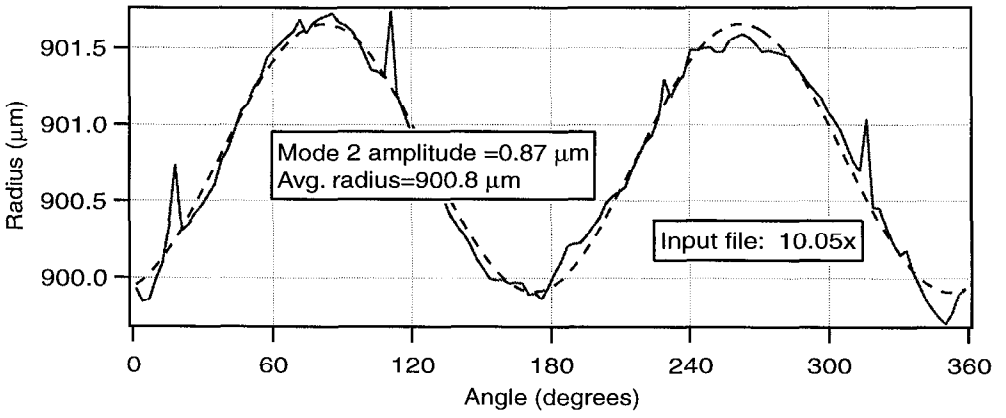


Figure 1. Example of current RACI analysis output. The dotted line curve is a calculated best mode two fit to the shadowgram OD data.

The RACI measurements showed sphericity ranging from 2.4 to 16.6 μm maximum *diameter* out-of-round, with an average of 5.0 μm in the 27 shells measured. From these shells, those having a diameter out-of-round value of less than 6 μm are possible candidates for Sphere Mapping. Six of the cleanest of those were mapped.

The Sphere Map results tracked the RACI *radius* out-of-round (ROOR) measurements. A comparison between Sphere Map and RACI ROOR results is listed in Table I. The Sphere Map traces exhibit the sharp spikes of surface debris that we have seen before, as well as some middle mode waves that are on the order of 1 μm high but hundreds of μm's across. Figure 2 is an example of a set of traces that happen to exhibit both characteristics.

Table I. Comparison of radius out-of-round data from the Sphere Mapper and RACI. The X, Y, and Z labels in the 2nd and 4th columns designate orthogonal measurements relative to the first X position, not the exact same orientation for the two different instrument characterizations.

	Sphere Mapper		RACI	
Shell		ROOR (μm)		ROOR (μm)
10.05	X	1.2	X	1.7
	Y	2.0	Y	1.8
	Z	1.2	Z	1.1
10.21	X	2.6	X	0.7
	Y	0.3	Y	1.6
	Z	1.5	Z	1.5
11.11	X	3.6	X	0.6
	Y	3.0	Y	1.4
	Z	1.7	Z	0.9

Shell		Sphere Mapper ROOR (μm)		RACI ROOR (μm)
11.23	X	0.5	X	.02
	Y	1.8	Y	1.2
	Z	2.5	Z	1.0
12.08	X	1.6	X	2.0
	Y	1.7	Y	1.6
	Z	1.0	Z	1.0
12.25	X	0.7	X	0.3
	Y	1.0	Y	1.3
	Z	1.7	Z	1.1

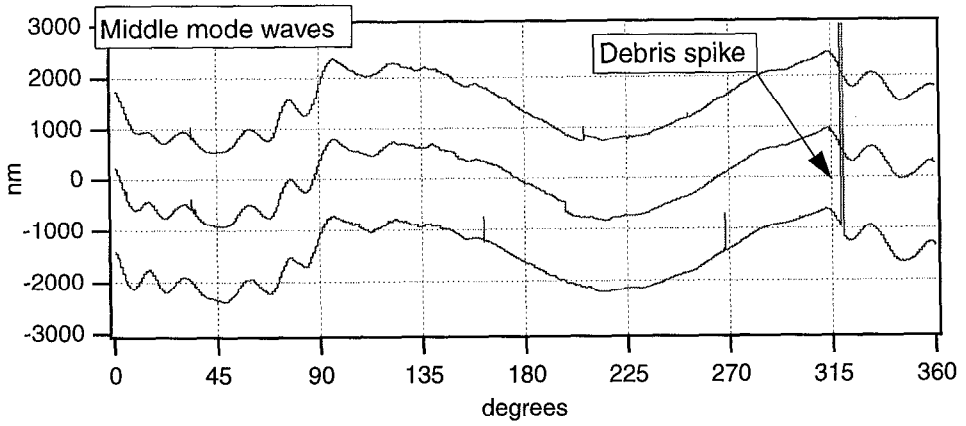


Figure 2. Example set of Sphere Mapper traces that happen to exhibit both the debris spikes and the middle mode waves.

The full set of Sphere Mapper results for this batch of shells is appended to the end of this report.

Table II presents the data of the selected subset of shells that were weighed. Using the mass, diameter and density of polystyrene for the shell, the wall thickness is calculated. The wall thickness ranged from 6 to 9 μm and showed little correlation with shell diameter, as illustrated in Figure 3.

Table II. Diameter, mass and calculated wall thickness data for shells that were weighed.

Shell	Ave. dia. (μm)	Mass (mg)	Wall thickness (μm)
10.21	1880.6	0.0805	7.5
10.32	1856.7	0.0927	8.7
11.11	1841.6	0.0829	7.2
11.23	1819.3	0.0711	6.5
11.27	1780.7	0.0891	8.2
11.36	1831.0	0.0733	7.0
12.08	1790.8	0.0876	8.2
12.12	1784.7	0.0805	7.7
12.25	1833.6	0.0675	5.9
12.26	1802.5	0.0804	7.3

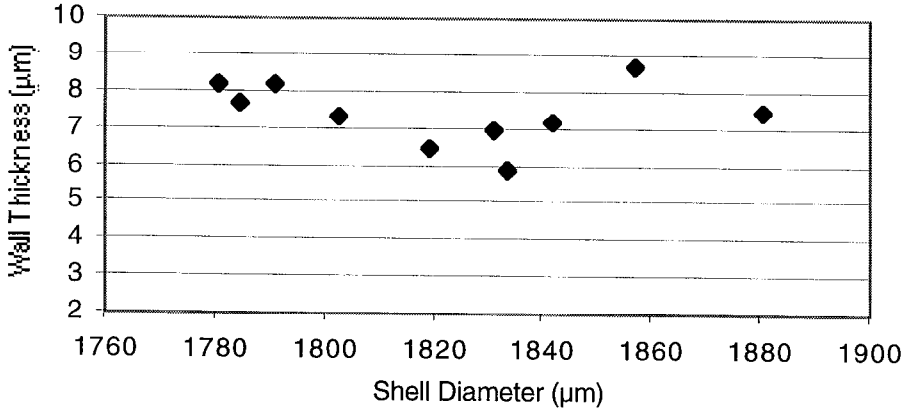
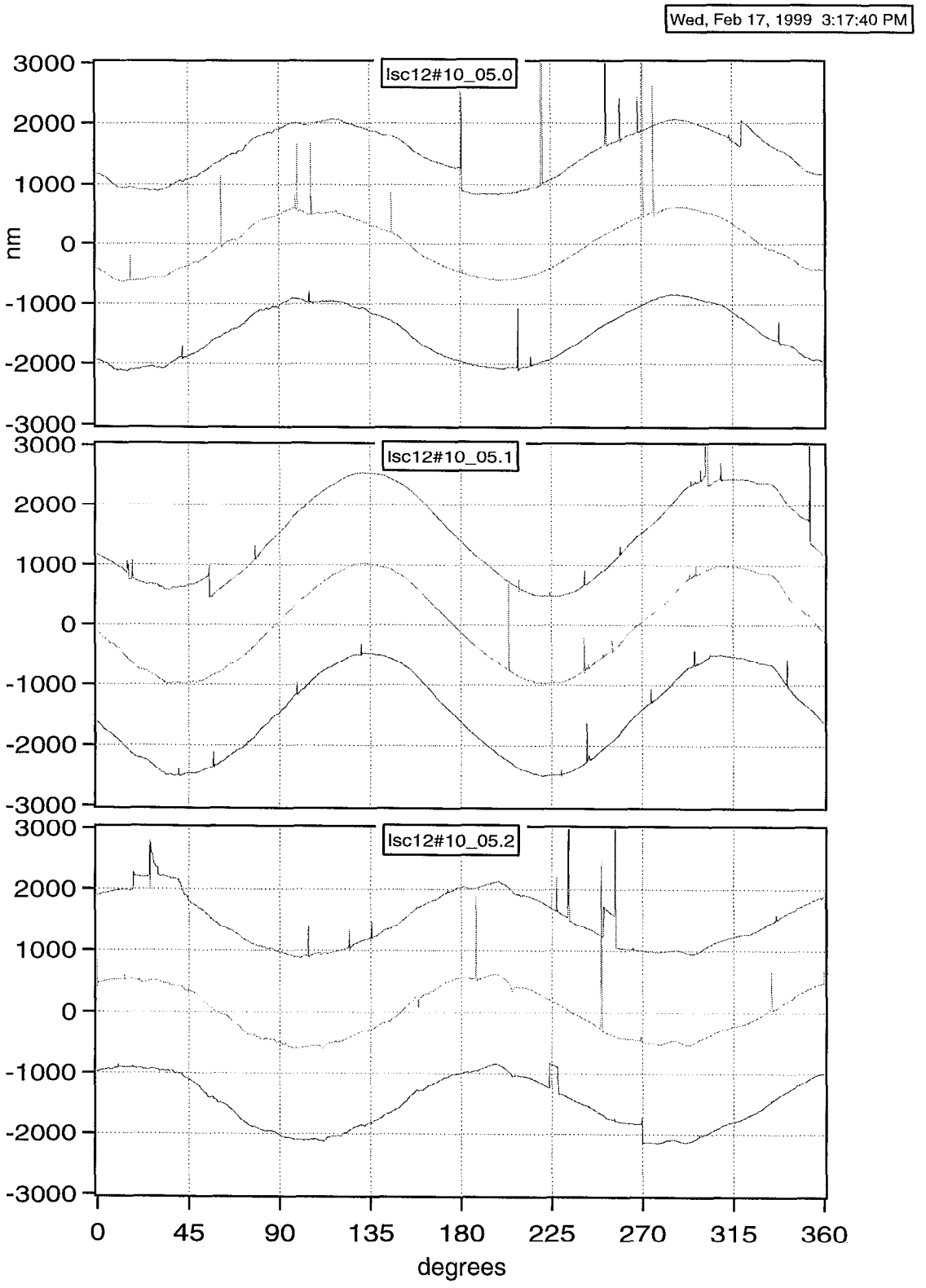


Figure 3. There is little correlation between shell diameter and wall thickness for ballistic furnace polystyrene shells.

The complete table of characterization for this batch of shells is appended to this report.

Appendix A

Complete Sphere Mapper results for shell batch LSC012.



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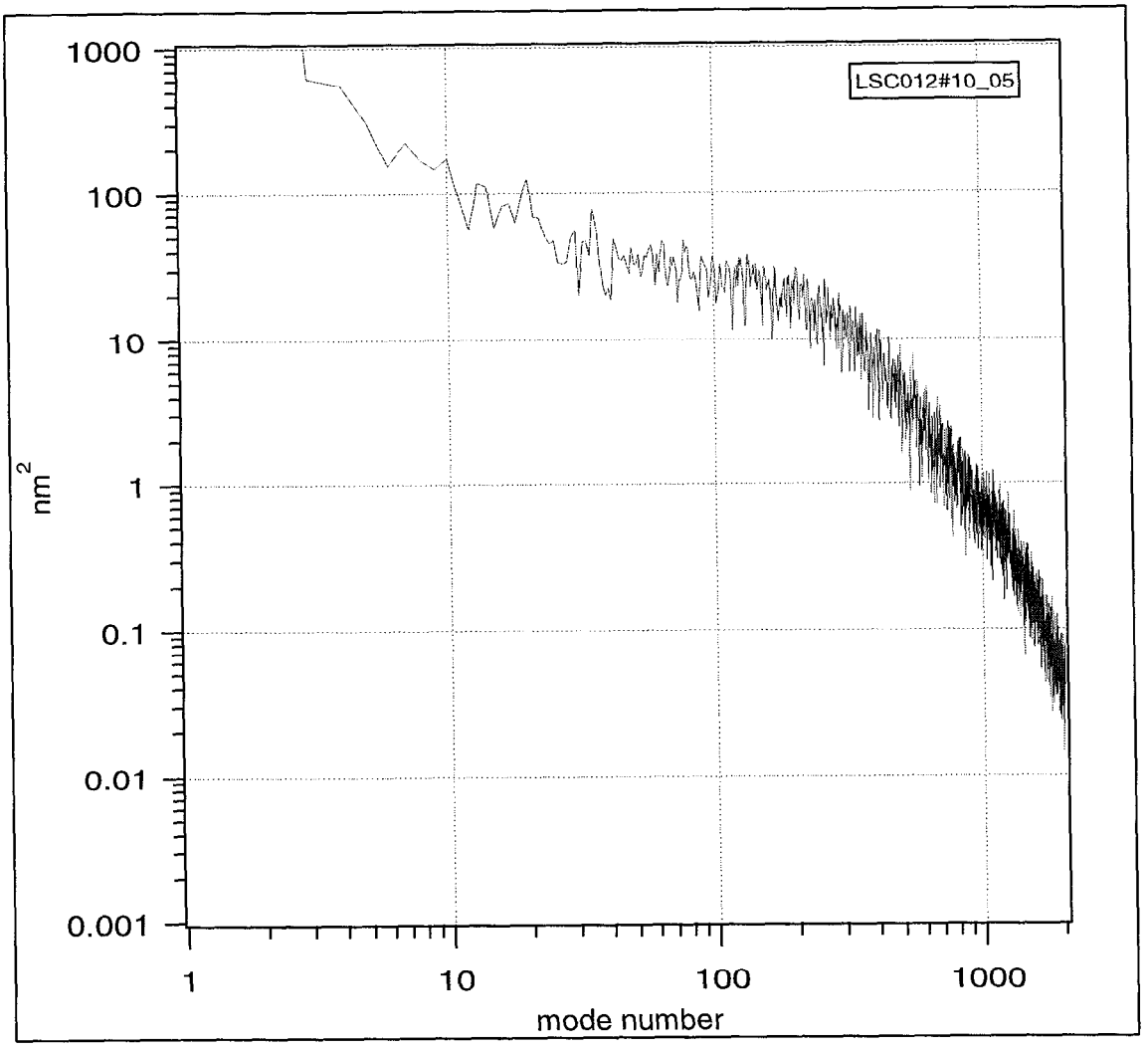

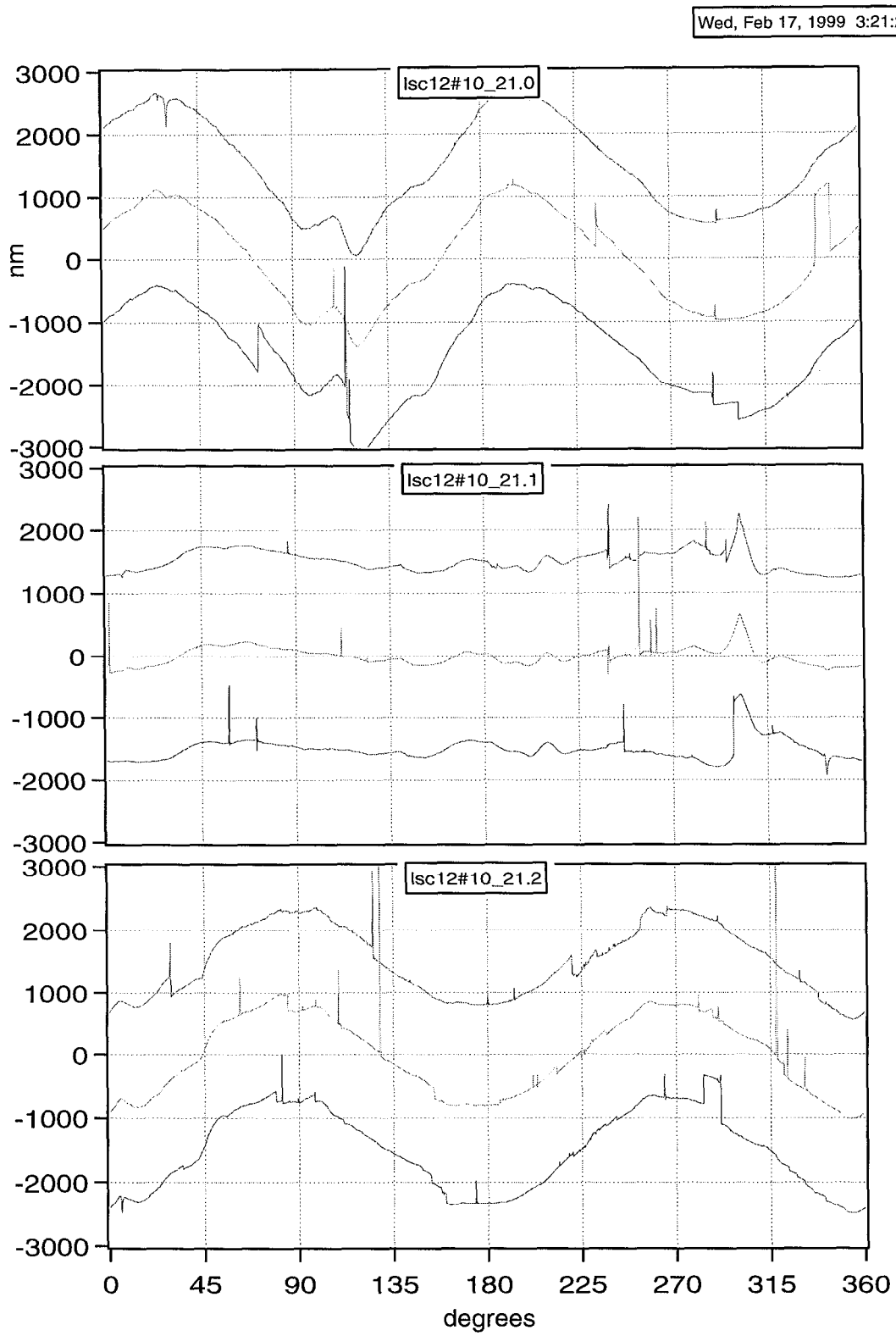
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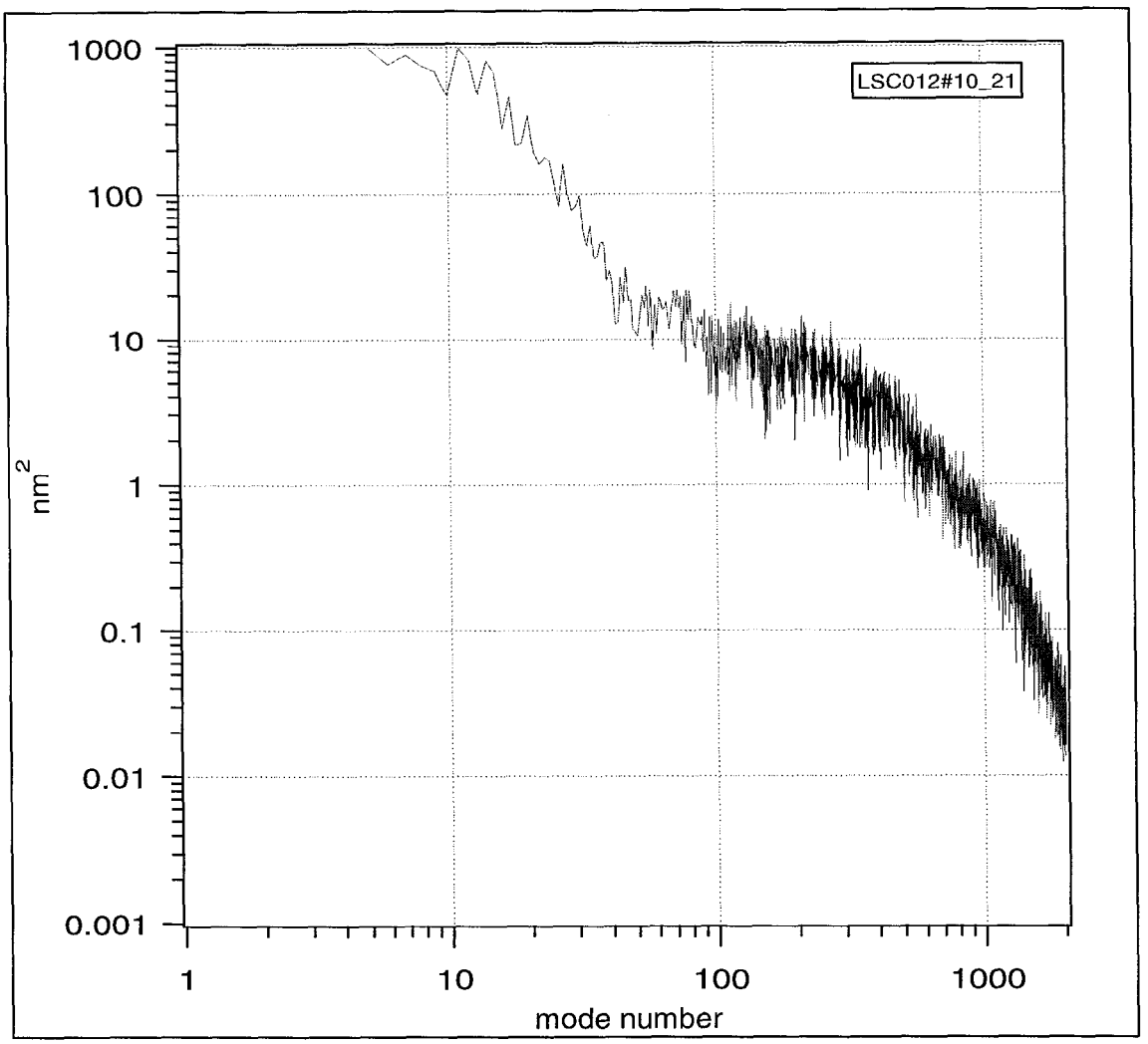

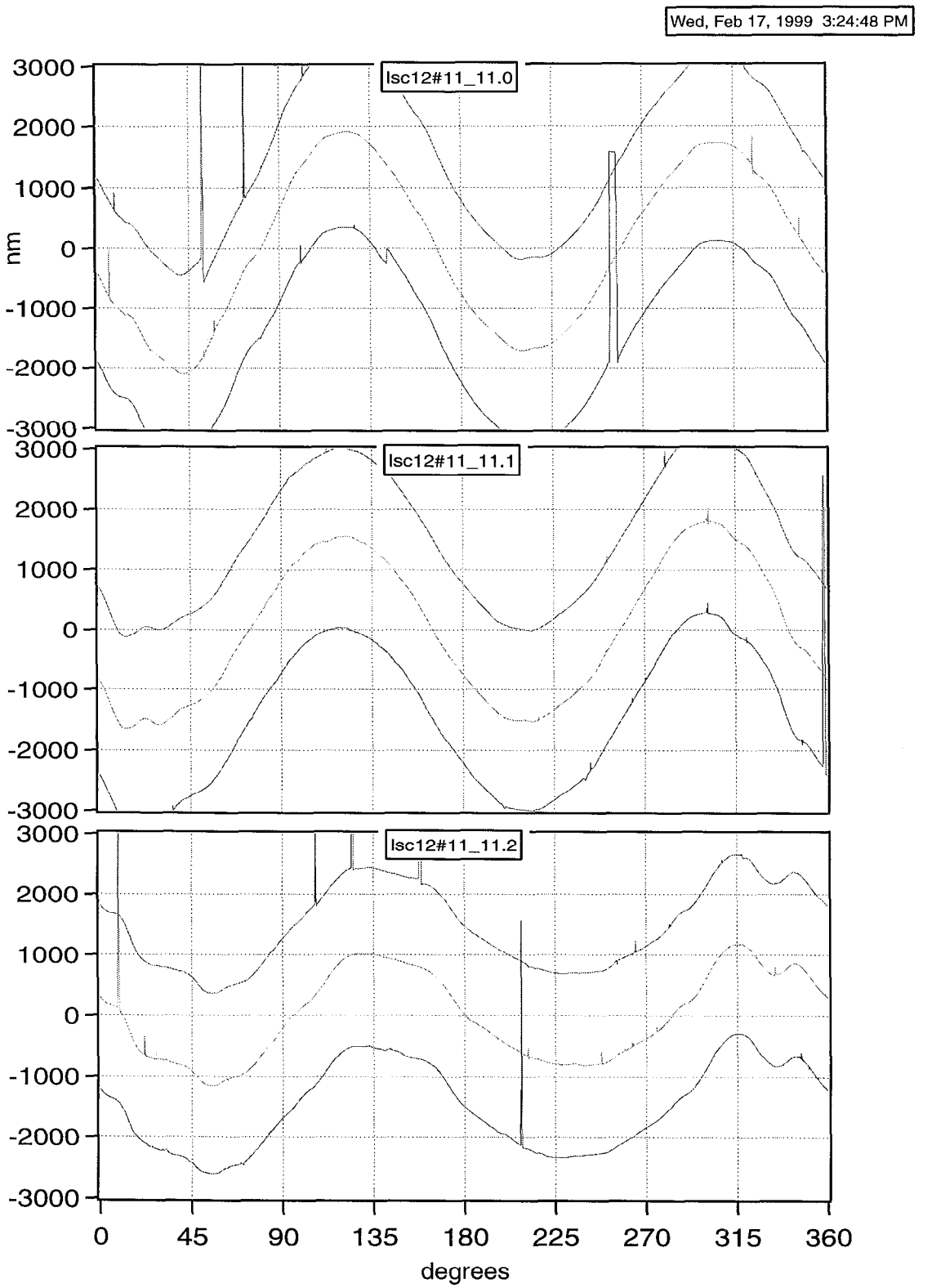
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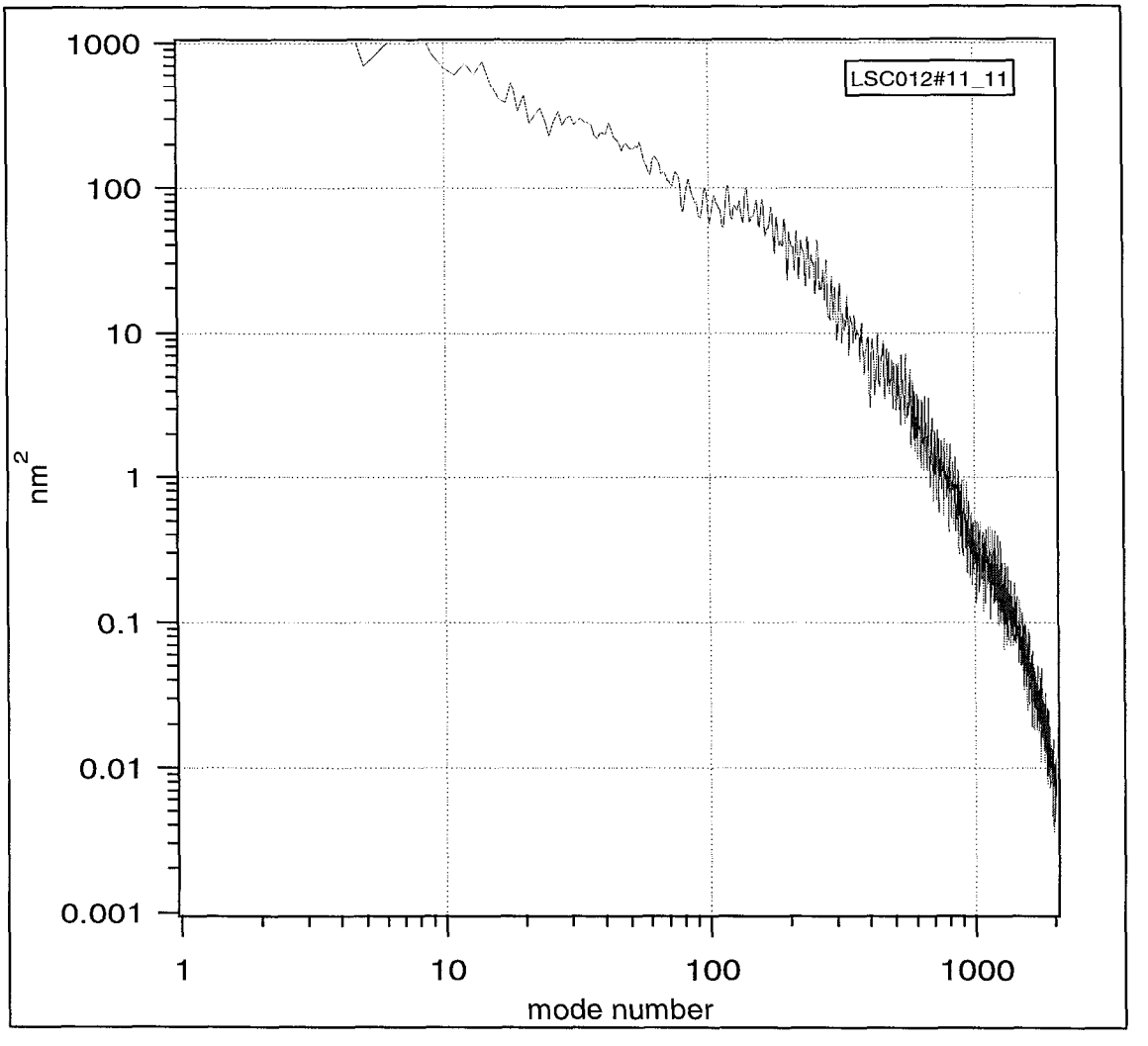

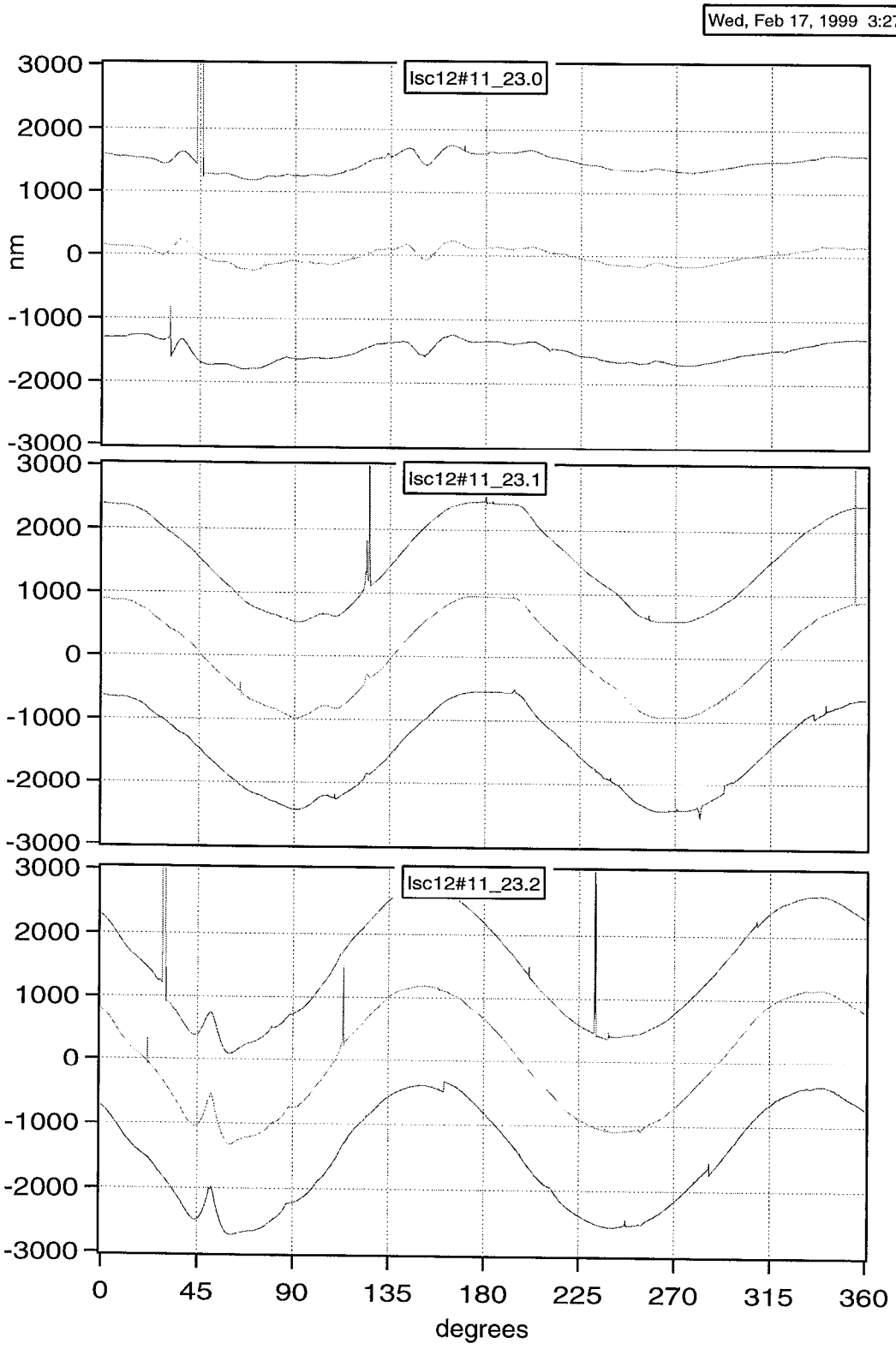
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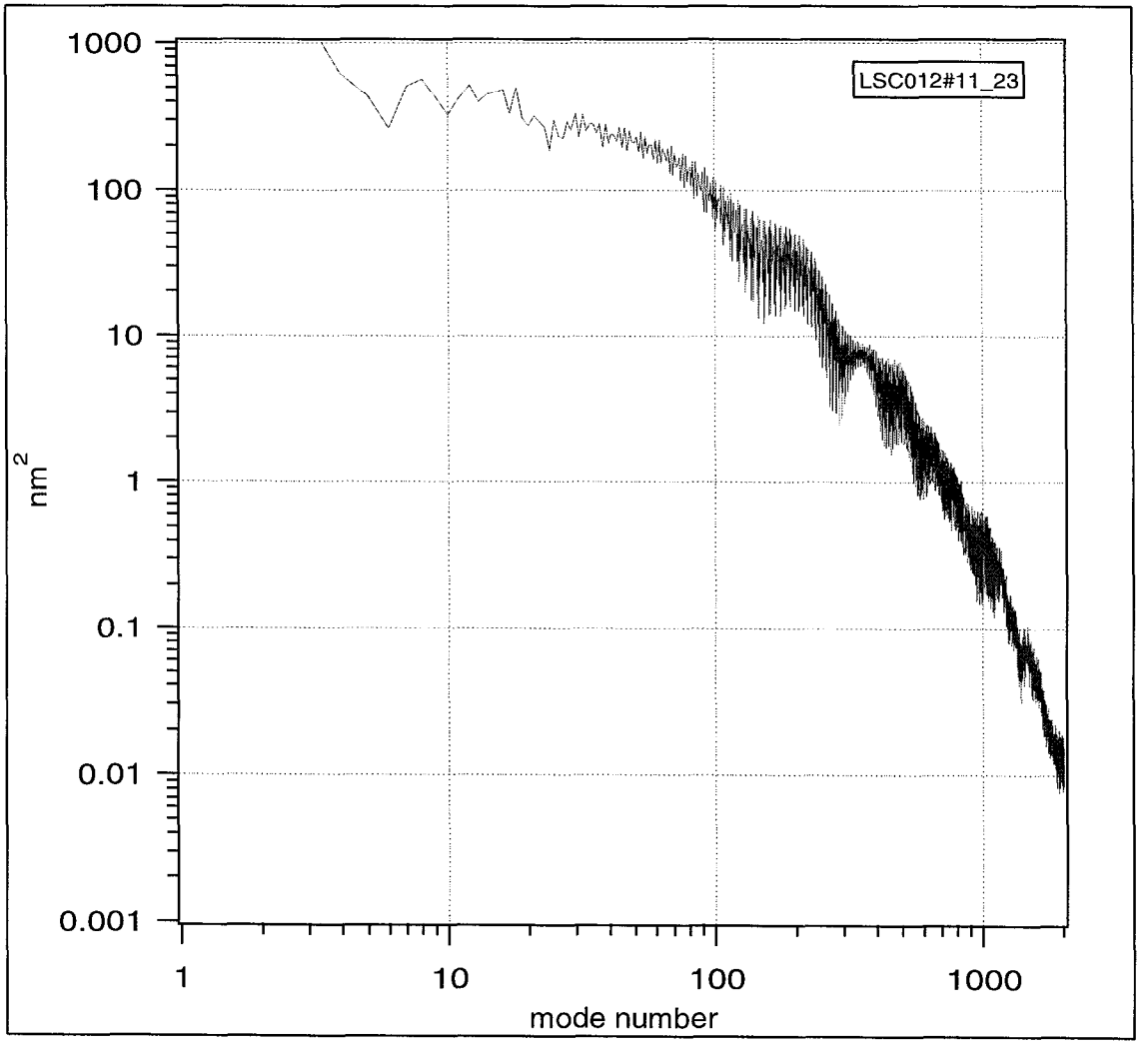

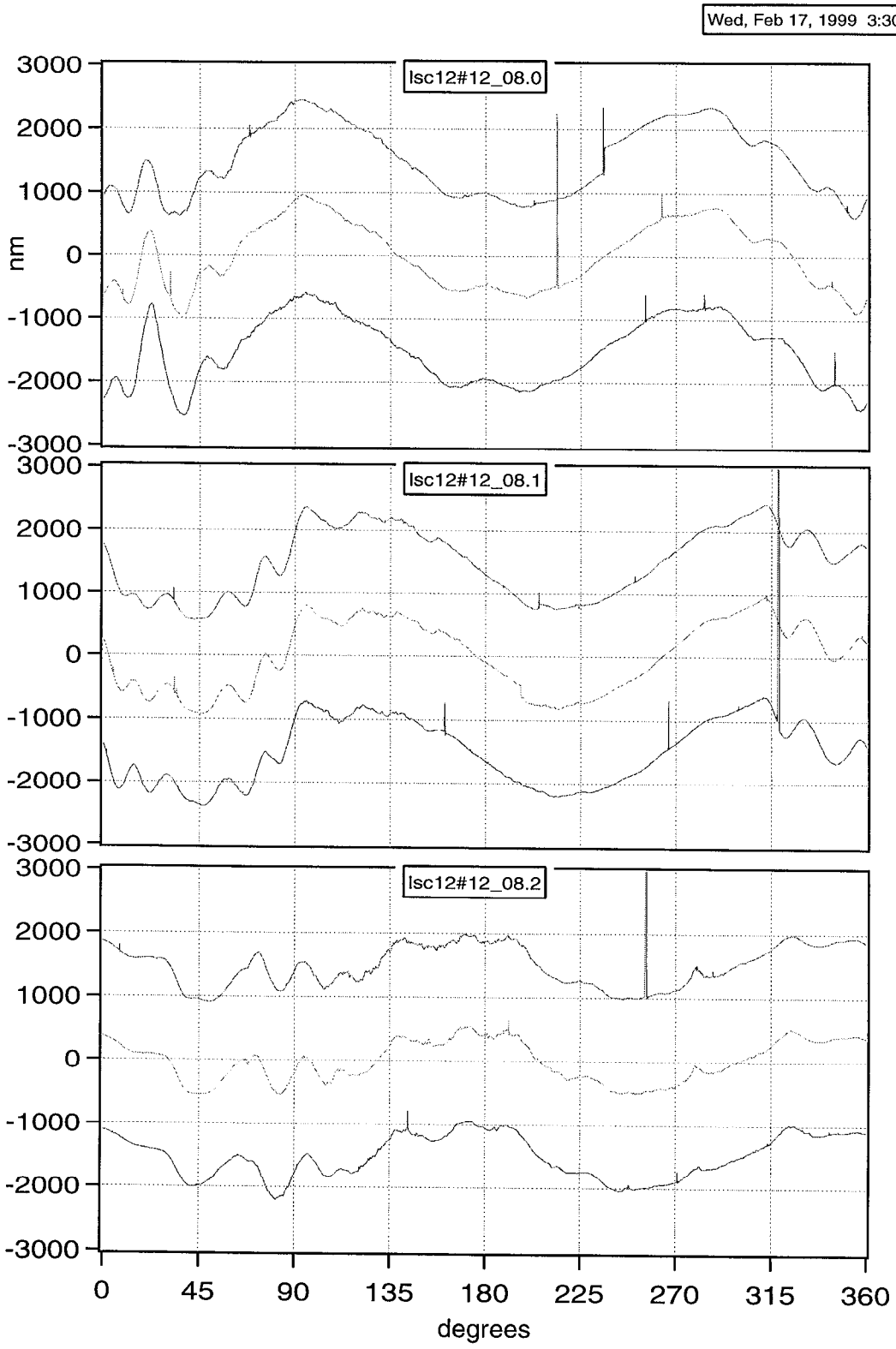
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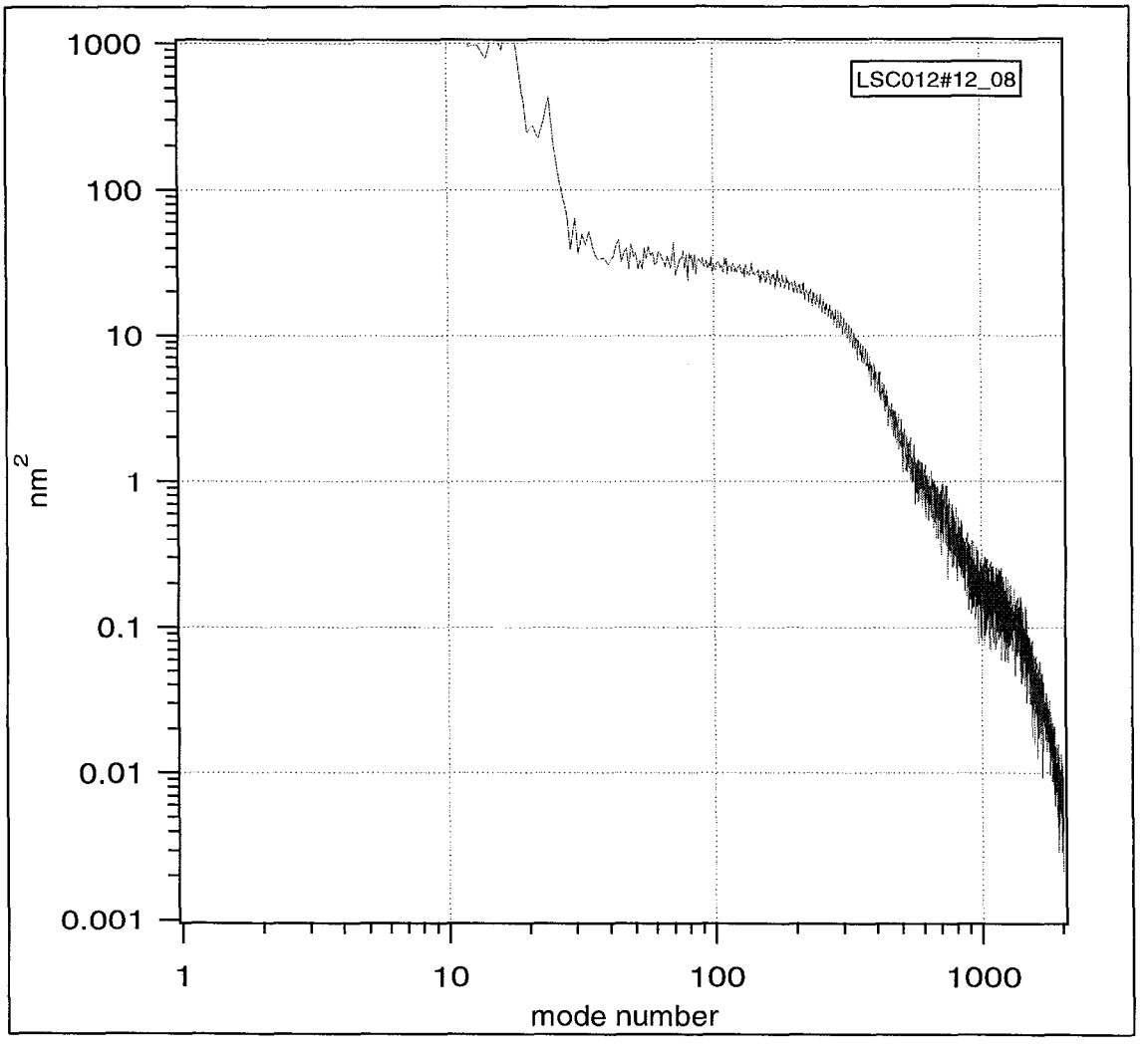

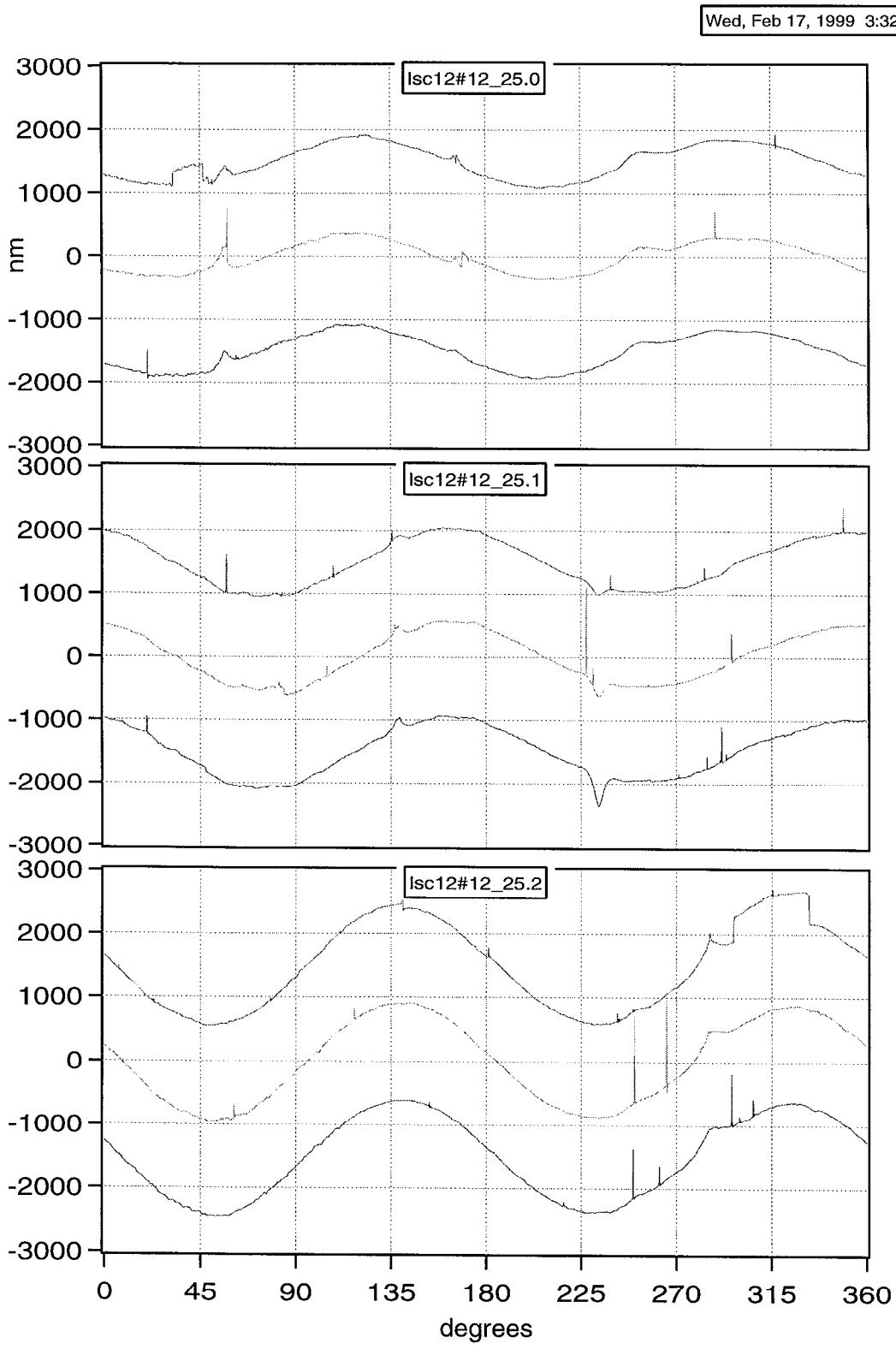
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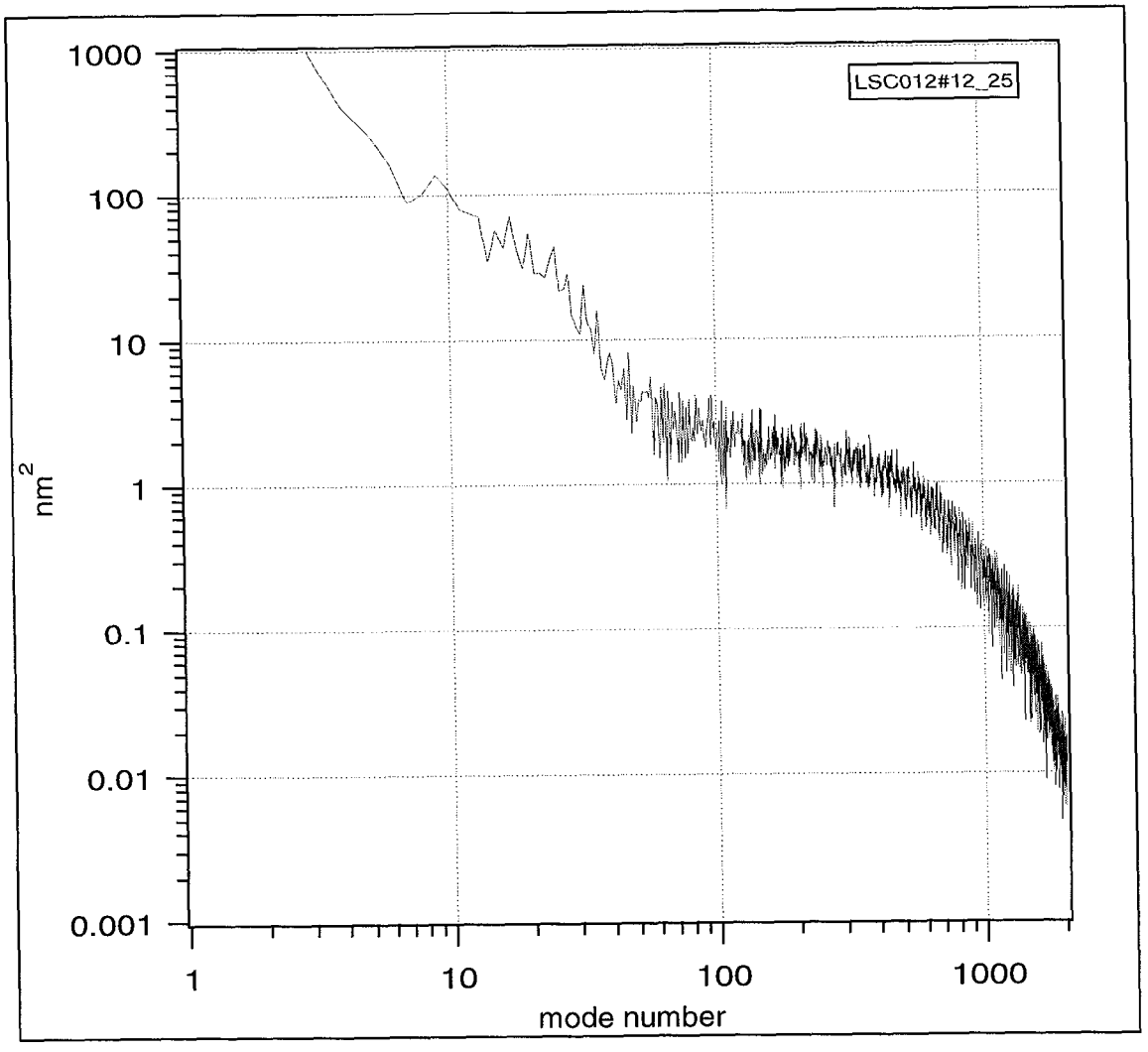

12/4/98			Russian Ballistic Furnace Polystyrene Shells				RACI boundary method				Radius OOR (μm)			Polystyrene Density:	1.05
LSC012															
Number	Pressure (atm)	Temp (°C)	Init granule dia (mm)	Nom. shell dia (μm)	Notes	axis	Avg. radius (μm)	Mode 2 amplit (μm)	Avg. dia (μm)	Avg. xyz dia (μm)	Radius OOR (μm)	MAX Radius OOR (μm)	Select for AFM SM	mass (mg)	Calc. Wall (μm)
2mm ball						x	999.6	0.3	1999.2	1999.1	0.6	0.7			
						y	999.5	0.3	1999		0.7				
						z	999.5	0.4	1999		0.7				
10.05	0.113	816	0.62	1804	clean except few small black particles on outside surface	x	900.8	0.9	1801.6	1801.6	1.7	1.8	✗	broke!	
						y	900.8	0.9	1801.6		1.8				
						z	900.8	0.6	1801.6		1.1				
10.17	0.106	868	0.73	1906	clean; isolated small particles		broken				0.0				
10.18	0.106	868	0.73	1808	clean	x	904	1.3	1808	1804.7	2.6	5.3			
						y	900.5	2.5	1801		5.1				
						z	902.6	2.6	1805.2		5.3				
10.21	0.103	835	0.69	1882	clean; isolated small particles	x	941	0.3	1882	1880.6	0.7	1.6	✗	0.0805	7.5
						y	939.9	0.8	1879.8		1.6				
						z	940	0.7	1880		1.5				
10.22	0.103	835	0.69	1938	small hole in shell; 1 large shard stuck to outside	x	965.9	0.7	1931.8	1935.1	1.4	2.2			
						y	968.6	0.3	1937.2		0.6				
						z	968.2	1.1	1936.4		2.2				
10.30	0.105	839	0.69	1810	a few small black particles; one embedded in wall; one polymer shard	x	903.9	0.7	1807.8	1807.5	1.4	1.8			
						y	904.1	0.3	1808.2		0.7				
						z	903.3	0.9	1806.6		1.8				
10.32	0.105	839	0.69	1852	several black particles stuck to shell outside	x	935.7	0.8	1871.4	1856.7	1.5	2.8		0.0927	8.7
						y	924.8	1.4	1849.6		2.8				
						z	924.5	0.9	1849		1.9				
10.35	0.104	828	0.67	1832	several black particles stuck to shell outside; one polymer shard stuck to outside	x	916.2	0.4	1832.4	1831.7	0.8	1.4			
						y	916.2	0.2	1832.4		0.4				
						z	915.1	0.7	1830.2		1.4				
11.09	0.104	828	0.67	1879	a few small black particles; one embedded in wall; one polymer shard stuck on outside	x	938.1	0.7	1876.2	1877.0	1.5	1.5			
						y	938.8	0.3	1877.6		0.5				
						z	938.6	0.1	1877.2		0.1				
11.11	0.104	828	0.67	1830	a few small black particles, clean otherwise	x	921.1	0.3	1842.2	1841.6	0.6	1.4	✗	0.0829	7.2
						y	920.4	0.7	1840.8		1.4				
						z	920.9	0.5	1841.8		0.9				
11.23	0.104	829	0.67	1820	clean; one or two small black particles	x	910	0.1	1820	1819.3	0.2	1.2	✗	0.0711	6.5
						y	909.2	0.6	1818.4		1.2				
						z	909.8	0.5	1819.6		1.0				
11.27	0.104	829	0.67	1780	clean	x	891.1	1.0	1782.2	1780.7	2.0	3.6		0.0891	8.2
						y	889.4	1.8	1778.8		3.6				
						z	890.5	1.4	1781		2.7				
11.32	0.103	852	0.67	1849	several small black particles, 2 large embedded particles	x	924	1.0	1848	1849.1	2.0	3.0			
						y	925.2	0.5	1850.4		0.9				
						z	924.4	1.5	1848.8		3.0				
11.35	0.103	852	0.67	1787	several black particles, a few small embedded	x	893	3.0	1786	1786.7	5.9	8.3			
						y	894.6	1.7	1789.2		3.4				
						z	892.4	4.1	1784.8		8.3				
11.36	0.105	846	0.67	1832	a few small black particles	x	915.5	1.0	1831	1831.0	2.1	2.4		0.0733	7.0
						y	915.2	1.2	1830.4		2.4				
						z	915.8	0.8	1831.6		1.5				
12.02	0.105	846	0.67	1792	clean, few scattered small black particles; one large polymer shard	x	895	1.1	1790	1791.1	2.2	2.2			
						y	895.3	1.0	1790.6		2.0				
						z	896.4	0.4	1792.8		0.8				
12.05	0.105	846	0.67	1809	several small polymer shards stuck on surface	x	904	1.1	1808	1808.4	2.2	2.4			
						y	904.7	0.7	1809.4		1.5				
						z	903.9	1.2	1807.8		2.4				
12.08	0.105	833	0.67	1792	clean; a few small black particles	x	894.9	1.0	1789.8	1790.8	2.0	2.0	✗	0.0876	8.2
						y	895.4	0.8	1790.8		1.6				
						z	895.9	0.5	1791.8		1.0				
12.12	0.107	842	0.67	1785	isolated embedded particles; small polymer shard	x	892	0.8	1784	1784.7	1.5	2.5		0.0805	7.7
						y	892.7	0.3	1785.4		0.7				
						z	892.3	1.2	1784.6		2.5				
12.13	0.107	842	0.67	1826	2 large polymer shards; 2 large embedded particles; few small black particles	x	912.1	1.1	1824.2	1824.7	2.1	2.1			
						y	912.9	0.4	1825.8		0.7				
						z	912	1.1	1824		2.1				
12.17	0.115	821	0.67	1864	clean except one polymer shard	x	931.6	1.4	1863.2	1863.2	2.9	2.9			
						y	931.1	1.3	1862.2		2.5				
						z	932.1	0.3	1864.2		0.7				
12.25	0.105	820	0.67	1834	clean!	x	917.1	0.1	1834.2	1833.6	0.3	1.3	✗	0.0675	5.9
						y	916.4	0.7	1832.8		1.3				
						z	916.9	0.6	1833.8		1.1				
12.26	0.105	820	0.67	1800	isolated small black particles	x	901.3	0.5	1802.6	1802.5	1.0	3.0		0.0804	7.3
						y	901.8	0.3	1803.6		0.6				
						z	900.7	1.5	1801.4		3.0				
12.28	0.105	820	0.67	1834	one polymer shard; one large embedded particle; a few small black particles	x	916.4	1.1	1832.8	1832.6	2.2	2.2			
						y	916.4	0.7	1832.8		1.4				
						z	916.4	0.5	1832.8		1.1				
12.33	0.106	855	0.67	1854	one large polymer shard; one small polymer shard; fairly clean otherwise	x	925.5	1.0	1851	1851.8	2.0	2.1			
						y	925.8	1.0	1851.6		2.1				
						z	926.4	0.5	1852.8		1.0				
12.35	0.106	855	0.67	1794	clean!	x	895.2	1.2	1790.4	1790.7	2.3	2.3			
						y	895.1	0.8	1790.2		1.7				
						z	895.7	0.3	1791.4		0.5				
12.36	0.106	855	0.67	1859	small polymer shards; several black particles	x	930.2	1.2	1860.4	1860.5	2.5	2.8			
						y	929.6	1.4	1859.2		2.8				
						z	931	0.3	1862		0.5				